Physical/biological Dynamics on the Finescale: Evaluation of Planktonic Thin Layer Processes

Timothy J. Cowles
College of Oceanic and Atmospheric Sciences
104 Oceanography Admin Bldg
Oregon State University
Corvallis, OR 97331-5503
Office: (541) 737-3966 FAX: (541) 737-2064 email: tjc@coas.oregonstate.edu

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LONG-TERM GOALS

Our long-term goal is to quantify the interactions between small-scale biological and physical processes within the upper ocean. This project has addressed that goal by examining specific scientific questions that relate the distribution and variability in sub-1m scale bio-optical properties with coincident spatial scales of physical properties.

OBJECTIVES

We have continued to focus on the processes that lead to persistent thin layers (20-40cm in thickness) of planktonic vertical structure in coastal environments. Our prior high-resolution observations of these features (e.g. Cowles et al 1998) have raised many questions about the role of these features in upper ocean trophic dynamics, optical and acoustical signal propagation, and remote sensing. In particular, we have noted striking correlations between thin layers of phytoplankton and small-scale vertical shear. There have also been observations by Holliday et al. (1998) that suggest that zooplankton aggregate on thin layers of phytoplankton. We addressed specific objectives during FY2002 in order to extend these observations and to understand the mechanisms of thin layer formation and persistence. These objectives can be framed as the following questions.

- To what extent is the formation and maintenance of planktonic small-scale structure driven by the vertical gradients in horizontal velocity?

- To what extent are trophic interactions constrained within thin layers of phytoplankton biomass?

In addition to these two research questions, we had a technical objective during this recent funding interval to redesign and initiate modification of the data acquisition components of our profiling system.

APPROACH

We approached our objectives for FY2002 through a series of ten one-day cruises conducted between April and September 2002. These cruises focused on the extent of thin layer occurrence over the middle of the continental shelf off Newport, Oregon, under a range of forcing conditions. We used our free-fall profiling system to obtain repeated profiles of temperature, salinity, density, small-scale vertical shear in horizontal velocity, along with bio-optical and bio-acoustical measures of plankton biomass. Bio-optical parameters obtained include 9 wavelengths of particulate absorption and beam attenuation (Wetlabs ac-9) along with pigment fluorescence. Bio-acoustical patterns (indices of zooplankton aggregation) were obtained with a 6-frequency acoustics systems (TAPS, BAE Systems) mounted on our free-fall profiler.

We conduct our short cruises over the center of the continental shelf (80m depth, 10 nm from shore), over a moored ADCP that provides 2m vertical resolution of horizontal velocity. This study site is within the survey area of a CODAR radio frequency array that provides hourly averages (1-km resolution) of surface currents, with wind data provided from nearby NOAA meteorological buoys. In addition, we have access to SeaWiFS imagery that can reveal mesoscale patterns in horizontal distributions of phytoplankton biomass over the continental shelf.

As reported in Annual Reports from previous years, high-resolution measurements of the vertical patterns of physical/biological properties form the basis for the evaluation of the mechanisms that produce persistent small-scale structure in the upper ocean. Several investigators have collaborated on this effort over the past few years, including Dr. Van Holliday, Dr. Percy Donaghay, Dr. Margaret Dekshenieks, Dr. Dian Gifford, Dr. Jan Rines, Dr. Mary Jane Perry, Dr. Sally MacIntyre, Dr. Alice Alldredge, and Dr. J. Ronald Zaneveld. This group continues to work to refine our understanding of small-scale processes by asking questions about the range of conditions that permit thin layer formation and persistence, the time scales of these processes, the horizontal extent of the resulting features, and the potential trophic impact of these features. The presence of such features also forces us to evaluate when and where we must alter our sampling strategies to obtain acceptable, if not perfectly accurate, estimates of the distribution of physical, chemical, and biological properties and rate processes in the upper ocean.

WORK COMPLETED

We conducted 14 cruises off the Oregon coast during this recent funding interval, obtaining approximately 100 profiles of high-resolution hydrographic, bio-optical, and bio-acoustical data. Most of these cruises were of one-day duration aboard the 54' *R/V Elakha*. We also obtained supplemental data during GLOBEC cruises on the *R/V Thompson* and *R/V Revelle*.

As part of the redesign of our data acquisition system, we have tested several technologies that we may use in the implementation of the new system. These technologies will permit us to collect multiple data streams (several instruments) into archives (all records time stamped and registered) that can be merged to produce a temporally (and spatially) coordinated sampling record.

We continued our collaboration during FY2002 with other ONR investigators involved in the 1998 East Sound Thin Layers experiments, and these efforts are now appearing in the reviewed literature (Alldredge et al. 2002, Eisner et al., *in press*, Cowles, *in review*, Dekshenieks et al., *in review*).

RESULTS

Vertical gradients over the continental shelf

Our series of vertical profiles over the mid-shelf during early September 2002 revealed one of our typically observed vertical patterns. We observed sharp vertical gradients in chlorophyll (based on fluorescence, Figure 1a) that were associated with vertical steps in stratification, as illustrated by the temperature gradient profile (Figure 1b). Consistent with these gradients were the vertical patterns of small-scale shear obtained with the Acoustic Doppler Velocimeter (Figure 2).

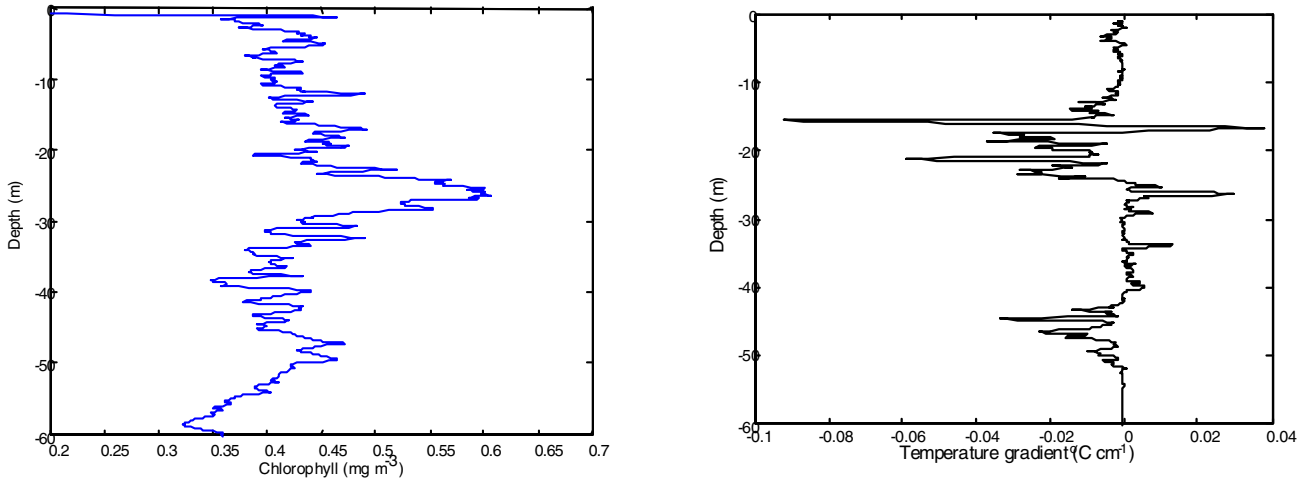

Figure 1. (Left panel) Vertical profile of phytoplankton biomass, September 2002, 10 nm west of Newport OR, showing a doubling of phytoplankton biomass over a 1m interval at 23m depth. (Right panel) Vertical gradient of temperature for the same profile in the left panel, illustrating the stratification coinciding with the phytoplankton gradient at 23m depth.

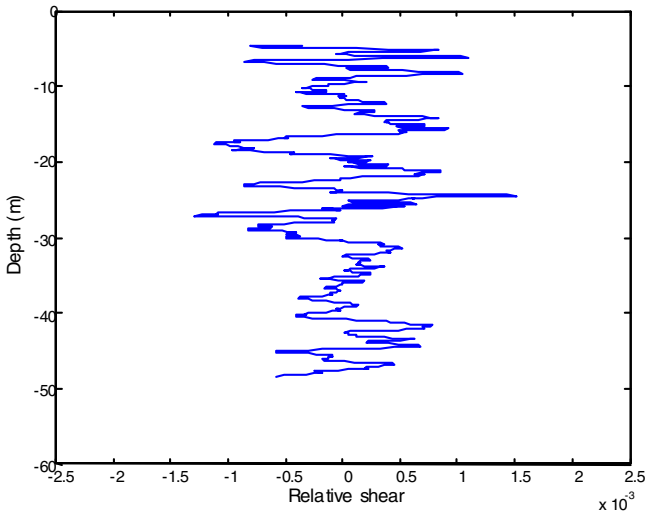

Figure 2. Vertical profile of relative velocity shear (from ADV), matching profile shown in Figure 1). Note the correlation between the sharp vertical gradients in chlorophyll, temperature and shear that span vertical intervals of 1-2m.

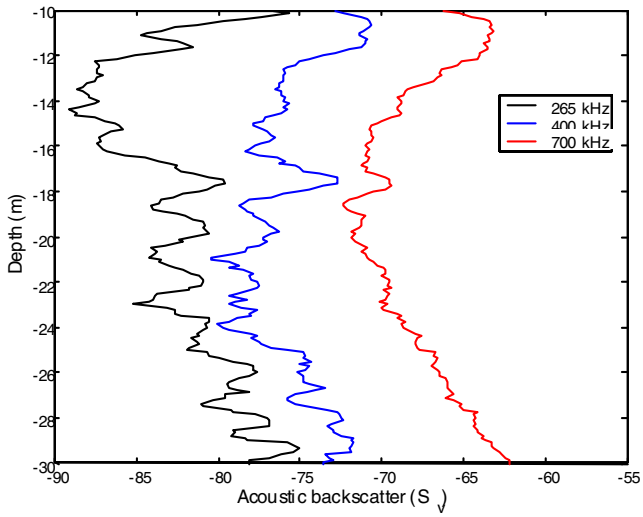

Figure 3. Vertical distribution of acoustic backscatter (S_v) for 265, 420 and 700 kHz frequencies over the Oregon continental shelf in June 2002 between 10-30m depth. Note the local maxima in S_v at 18m depth, just 2m below a local minimum in S_v. These patterns were correlated with a local maximum in phytoplankton biomass between 17-20m (not shown).

We have found that zooplankton patterns, determined acoustically with the 6-frequency TAPS, also have sharp vertical gradients over the Oregon shelf (Figure 3). In addition to significant changes in S_v within 2m intervals (note the 8 dB change in 265 kHz at 17m), the relative changes between the three

frequencies suggest significant compositional changes in the target populations over these narrow vertical intervals.

Data Acquisition System

We have developed a series of XML schemas that permit easy configuration of our new data acquisition approach to accommodate various combinations of instruments in different deployment scenarios. We are testing a software system developed by NASA for archiving and time stamping multiple data streams called the Ring Buffered Network Bus (RBNB) Data Turbine. We have completed the first phase of performance testing of the RBNB software. The results have been positive, and we plan on developing our first prototype system using the RBNB Data Turbine software.

IMPACT/APPLICATION

Our results suggest a tight link between the vertical scales of horizontal velocity changes and patterns of small-scale planktonic structure. This linkage indicates that the vertical gradients in *horizontal* processes, rather than *vertical* processes themselves, may be the key organizing processes in plankton dynamics. Our work with biological small-scale structure suggests that previous observations of small-scale biological patchiness may not have been observations of stochastic fluctuations in biological structure (i.e., patchiness), but under-sampled observations of persistent, small-scale structure. This finescale organization of planktonic biomass forces a re-evaluation of water column rate processes, and challenges our existing paradigms for sampling and experimentation over scales of meters and 10's of meters.

TRANSITIONS

The results from repeated sets of profiles from the Oregon continental shelf provide additional insights into the mechanisms that create that persistent pattern on small-scales. Continued evaluation of these mechanisms will be essential for prediction of the impact of persistent small-scale pattern on the attenuation of optical and acoustic signals in the upper ocean. These observational techniques may now be applied at various oceanic study sites, thus extending our appreciation of the role that small-scale processes may play in our estimates of water column production.

RELATED PROJECTS

We have active collaborations with the following ONR Principal Investigators:

Dr. Percy Donaghay, University of Rhode Island
Dr. Jan Rines, University of Rhode Island
Dr. Dian Gifford, University of Rhode Island
Dr. David Smith, University of Rhode Island
Dr. Alice Alldredge, UC Santa Barbara
Dr. Sally MacIntyre, UC Santa Barbara
Dr. Mary Jane Perry, University of Maine
Dr. Van Holliday, BAE Systems (formerly TRACOR)
Dr. J.R. Zaneveld, Oregon State University

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PATENTS

None